

OBSTETRICS

Evidence-based surgery for cesarean delivery: an updated systematic review

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The objective of our systematic review was to provide updated evidence-based guidance for surgical decisions during cesarean delivery (CD). We performed an English-language MEDLINE, PubMed, and COCHRANE search with the terms, cesarean section, cesarean delivery, cesarean, pregnancy, and randomized trials, plus each technical aspect of CD. Randomized control trials (RCTs) involving any aspect of CD technique from Jan. 1, 2005, to Sept. 1, 2012, were evaluated to update a previous systematic review. We also summarized Cochrane reviews, systematic reviews, and metaanalyses if they included additional RCTs since this review. We identified 73 RCTs, 10 metaanalyses and/or systematic reviews, and 12 Cochrane reviews during this time frame. Recommendations with high levels of certainty as defined by the US Preventive Services Task Force favor pre-skin incision prophylactic antibiotics, cephalad-caudad blunt uterine extension, spontaneous placental removal, surgeon preference on uterine exteriorization, single-layer uterine closure when future fertility is undesired, and suture closure of the subcutaneous tissue when thickness is 2 cm or greater and do not favor manual cervical dilation, subcutaneous drains, or supplemental oxygen for the reduction of morbidity from infection. The technical aspect of CD with high-quality, evidence-based recommendations should be adopted. Although 73 RCTs over the past 8 years is encouraging, additional well-designed, adequately powered trials on the specific technical aspects of CD are warranted.

Key words: cesarean delivery, evidence-based medicine, randomized controlled trials, systematic review

Cesarean delivery (CD) is the most common major surgery performed and the 1.3 million women who undergo

this operation per year in the United States face substantially increased risks of maternal morbidity and mortality compared with women who deliver vaginally.¹⁻³

Previously, Berghella et al⁴ summarized 150 randomized clinical trials (RCTs) published from 1960 to 2004 and made evidence based recommendations for each step of CD using US Preventive Services Task Force (USPSTF) definitions. Utilizing similar criteria as their review, our objective was to update and summarize the current body of literature regarding each technical step of CD.

Materials and methods

This review was modeled on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.⁵ We performed an English-language MEDLINE, PubMed, and

COCHRANE database search with the terms, cesarean section, cesarean delivery, cesarean, pregnancy, and randomized trials plus each technical aspect of the operation (eg, lateral tilt, skin cleansing). Because the literature search for previous publication on this topic ended on Dec. 31, 2004, we searched from Jan. 1, 2005, to Sept. 1, 2012.⁴

Each abstract was evaluated by 2 authors (J.D.D. and H.M.F.); all pertinent references from the manuscripts were obtained and reviewed. We included RCTs that reported clinical outcomes. Metaanalyses and Cochrane and systematic reviews were included only if there were additional RCTs performed in our 2005-2012 time frame. After review, evidence-based recommendations using terminology defined by the USPSTF (Table 1)⁶ were reported as changed, unchanged, or new compared with the original manuscript. If, in the previous review, a CD technique was assigned a USPSTF grade A or B (technique is recommended) and no new studies were added during our 2005-2012 time frame, we did not change the grade assigned by Berghella et al.⁴ If, however, we deemed a new study (or studies) compelling enough (alone or in combination) to alter the grade, we did so by consensus of all the authors.

Results

From 5361 abstracts retrieved by our search, we identified 73 RCTs, 10 metaanalyses or systematic reviews, and 12 Cochrane reviews since Jan. 1, 2005. All technical aspects of CD with evidence-based recommendations and levels of certainty are summarized in Table 2. Additional techniques with RCTs since the review by Berghella et al⁴ include the following items: thromboprophylaxis, preoperative vaginal cleaning, indwelling bladder catheterization, Misgav-Ladach

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TABLE 1

Standard recommendation language and quality of evidence according to the method outlined by the USPSTF⁶

Grade	Definition	Suggestions for practice
A	The USPSTF recommends the service. There is high certainty that the net benefit is substantial.	Offer or provide this service.
B	The USPSTF recommends the service. There is high certainty that the net benefit is moderate or there is moderate certainty that the net benefit is moderate to substantial	Offer or provide this service.
C	Note: The following statement is undergoing revision. Clinicians may provide this service to selected patients, depending on individual circumstances. However, for most individuals without signs or symptoms, there is likely to be only a small benefit from this service.	Offer or provide this service only if other considerations support the offering or providing the service in an individual patient.
D	The USPSTF recommends against the service. There is moderate or high certainty that the service has no net benefit or that the harms outweigh the benefits.	Discourage the use of this service.
I	The USPSTF concludes that the current evidence is insufficient to assess the balance of benefits and harms of the service. Evidence is lacking, of poor quality, or conflicting, and the balance of benefits and harms cannot be determined.	If the service is offered, patients should understand the uncertainty about the balance of benefits and harms.
Level of certainty	Description	
High	The available evidence usually includes consistent results from well-designed, well-conducted studies in representative primary care populations. These studies assess the effects of the preventive service on health outcomes. This conclusion is therefore unlikely to be strongly affected by the results of future studies.	
Moderate	The available evidence is sufficient to determine the effects of the preventive service on health outcomes, but confidence in the estimate is constrained by such factors as: <ul style="list-style-type: none"> • The number, size, or quality of individual studies. • Inconsistency of findings across individual studies. • Limited generalizability of findings to routine primary care practice. • Lack of coherence in the chain of evidence. As more information becomes available, the magnitude or direction of the observed effect could change, and this change may be large enough to alter the conclusion.	
Low	The available evidence is insufficient to assess effects on health outcomes. Evidence is insufficient because of: <ul style="list-style-type: none"> • The limited number or size of studies. • Important flaws in study design or methods. • Inconsistency of findings across individual studies. • Gaps in the chain of evidence. • Findings not generalizable to routine primary care practice. • Lack of information on important health outcomes. More information may allow estimation of effects on health outcomes.	

USPSTF, US Preventive Services Task Force.

Dahlke. Evidence-based cesarean delivery. *Am J Obstet Gynecol* 2013.

technique, supplemental oxygen, self-retaining retractors, additional uterine atony prophylaxis measures, placental drainage, manual cervical dilation, and elective appendectomy.

Preoperative preparation

Prophylactic antibiotics

Prophylactic antibiotic regimens comparing single-dose antibiotics with extended-spectrum coverage have been evaluated in 3 new RCTs.⁷⁻⁹ Specifically, randomized

trials using ampicillin/sulbactam,⁷ triple antibiotic (ampicillin, gentamicin, and metronidazole),⁸ and penicillin and cephalothin⁹ did not demonstrate improved outcomes compared with standard cephalosporin prophylaxis. Thus, prophylaxis with a single dose of ampicillin or first-generation cephalosporins, such as cefazolin, should be administered in all women undergoing CD^{5,10} (recommendation: A; level of certainty: high; Table 1; unchanged).

Timing of antibiotic administration (preoperative vs after cord clamp) has been evaluated in 4 new RCTs¹¹⁻¹⁴ and 1 metaanalysis.¹⁵ Two trials^{11,14} did not show a difference in maternal morbidity from infection, whereas 2 trials^{12,13} demonstrated a significant decrease in maternal morbidity from infection when antibiotics were given preoperatively with no increase in neonatal complications. A metaanalysis of 5 RCTs noted that preoperative administration (15-60

TABLE 2
Evidence-based recommendations for CD

CD technical aspect (comment)	Recommendation ^a	Level of certainty ^a	References
Prophylactic antibiotics			
Yes (all CD)	A- Recommends	High	7-10,102
Type (ampicillin or first-generation cep)	A- Recommends	High	101,103
Administration (systemic)	A- Recommends	High	101
Multiple doses (NR)	D- Recommends Against	High	101
Timing (preskin incision)	A- Recommends	High	11-15,103-105
Thromboprophylaxis ^b	I- Insufficient Evidence	Low	16-18
Lateral tilt	I	Low	106-110
Skin cleansing (CHG or iodine)	I- Insufficient Evidence	Low	111,112
Preoperative vaginal preparation (iodine) ^b	B- Recommends	Moderate	20-22
Supplemental oxygen (NR) ^b	D ^b	High ^b	29,30
Indwelling bladder catheter^b			
None ^b	C ^b	Moderate ^b	23-26
Immediate or 24-h removal ^b	C ^b	Moderate ^b	27
Adhesive drape (NR)	D	Moderate	113,114
Skin incision			
Type (Pfaannenstiel or Joel-Cohen)	C- Possible small benefit	Moderate	31-36,115-123
Length	I- Insufficient Evidence	Low	123
Second scalpel (NR)	D- Recommends Against	Moderate	124
Subcutaneous incision	I- Insufficient Evidence	Low	
Fascial incision	I- Insufficient Evidence	Low	
Rectus muscle cutting (NR)	D- Recommends Against	Moderate	125
Dissection of fascia off rectus	I- Insufficient Evidence	Low	37
Opening of peritoneum	I- Insufficient Evidence	Low	
Self-retaining retractors ^b	I- Insufficient Evidence	Low	41
Bladder flap development (NR)	D- Recommends Against	Moderate	38-40,126
Uterine incision			
Type (transverse)	B- Recommends	Moderate	127,128
Stapling device (NR)	D- Recommends Against	Moderate	129-131
Expansion (blunt, cephalad-caudad) ^b	A- Recommends	High	42-44,132,133
Instrumental delivery	I	Low	134,135
Prevention of postpartum hemorrhage			
Oxytocin or placebo (oxytocin) ^b	B ^b	High ^b	136
Infusion rate (10-40 IU over 4-8 h) ^b	B ^b	High ^b	46,47,49
Carbetocin or oxytocin	C	Moderate	45,50,137,138
Miso plus oxytocin or oxytocin only (oxytocin) ^b	D ^b	Moderate ^b	51-55
Oxytocin or tranexamic acid ^b	B ^b	Moderate ^b	48,56,57

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(continued)

TABLE 2

Evidence-based recommendations for CD (continued)

CD technical aspect (comment)	Recommendation ^a	Level of certainty ^a	References
Placental removal			
Spontaneous	A-Recommends	High	139-145
Glove change (NR)	D-Recommends Against	Moderate	139
Placental drainage ^b	I-Insufficient Evidence	Moderate	58
Uterine exteriorization (surgeon preference ^b)	C-Surgeon Preference	High	59-66,142,146-150
Cleaning of uterus	I-Insufficient Evidence	Low	
Cervical dilation (NR) ^b	D-Recommend Against	High	67-70
Closure of uterine incision^b			
Undesired fertility (1-layer) ^b	A-Recommends	High	44,72,75,151,152
Desired fertility ^b	C-Surgeon Preference	Moderate	
Decidua/serosa incorporation	I-Insufficient Evidence	Low	
Continuous suture	B-Recommends	Moderate	153
Elective appendectomy (NR) ^b	D ^b	Moderate ^b	73
Intraabdominal irrigation			
Saline (NR) ^b	D ^b	Moderate ^b	74,154
Peritoneal closure	C-Surgeon's Preference	Moderate	75-84,155-165
Rectus muscles reapproximation	I	Low	
Technique of fascial closure			
Running or locked (running, unlocked)	I-Insufficient Evidence	Low	
Sharp or blunt needles (blunt) ^b	A-Recommends	Moderate	84,85,166
Irrigation of subcutaneous tissue	I-Insufficient Evidence	Low	
Subcutaneous tissue^b			
≥2 cm thickness ^b			
Closure or nonclosure (closure) ^b	A-Recommends	High	167-175
Closure or drain (closure) ^b	A-Recommends	High	75,87
Closure or drain plus closure (closure only) ^b	A-Recommends	High	88
Closure of skin			
Staples or subcuticular suture	C-Surgeon Preference	Moderate	89-96,176,177

Parentheses indicate the preferred technique. Other recommendations are from Berghella et al.⁴

CD, cesarean delivery; Ceph, cephalosporin; CHG, chlorhexidine gluconate; Miso, misoprostol; NR, not recommended; TA, tranexamic acid.

^a See Table 1 for recommendation and level of certainty definitions; ^b Indicates changed or new recommendations based on this review.

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minutes prior to skin incision) significantly reduced the risk of postpartum endometritis (4% vs 8.8%, relative risk [RR], 0.47; 95% confidence interval [CI], 0.26–0.85) and total morbidity from infection (7.2% vs 14.3%, RR, 0.50; 95% CI, 0.33–0.78), with no significant effect on suspected neonatal sepsis (RR, 1; 95% CI, 0.70–1.42), proven sepsis (RR, 0.93; 95% CI, 0.45–1.96), or neonatal

intensive care unit admissions (RR, 1.07; 95% CI, 0.51–2.24).¹⁵ These trials support preoperative prophylactic antibiotic administration before all CDs (recommendation: A; level of certainty: high; Table 1; changed).

Thromboprophylaxis

Thromboprophylaxis during CD was not previously reviewed. No clinical

trials using compression stockings and/or pneumatic compressions stockings have been conducted nor has there been a comparison of these modalities to heparin. Three RCTs (total n = 267) have evaluated the efficacy of unfractionated heparin¹⁶ or low-molecular-weight heparin.^{17,18} Given that the risk of CD-associated venous thromboembolism (VTE) is estimated to be 0.23%,¹⁹

TABLE 3
Summary of general CD operative techniques

Variable	PKM	JCM	MLM	MMLM
Skin incision	Pfannenstiel ^a	Joel-Cohen ^b	Joel-Cohen ^b	Pfannenstiel ^a
Subcutaneous layer closure	Sharp dissection	Blunt dissection	Blunt dissection	Blunt dissection
Fascia opening	Sharp extension	Blunt extension	Blunt extension	Blunt extension
Peritoneal opening	Sharp entry	Blunt entry	Blunt entry	Blunt entry
Uterine incision	Sharp superficial, then blunt entry	Sharp superficial, then blunt entry	Sharp superficial, then blunt entry	Sharp superficial, then blunt entry
Placenta removal	Manual	Spontaneous	Manual	Spontaneous
Uterine closure	Single layer, interrupted	Single layer, interrupted	Single layer, running	Single layer, running
Peritoneal closure	Closed	Not closed	Not closed	Closed
Fascia closure	Interrupted	Interrupted	Continuous	Continuous
Subcutaneous closure	Not sutured	Not sutured	Not sutured	Not sutured
Skin closure	Continuous suture	Continuous suture	Mattress sutures	Continuous suture

CD, cesarean delivery; JCM, Joel-Cohen method; MLM, Misgav-Ladach method; MMLM, Modified Misgav-Ladach method; PKM, Pfannenstiel-Kerr method.

^a Pfannenstiel skin incision is slightly curved, 2-3 cm or 2 fingers above the symphysis pubis, with the midportion of the incision within the shaved area of the pubic hair; ^b Joel-Cohen incision is straight, 3 cm below the line that joins the anterior superior iliac spines, slightly more cephalad than Pfannenstiel.

Modified from Hofmyr,³⁶ Naki,³¹ and Xavier.³⁴ Some studies report slight variations to these techniques.

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these trials are collectively underpowered to provide recommendation guidance (recommendation I; level of certainty: low; Table 1; new).

Preoperative vaginal preparation

This type of surgical preparation has been evaluated in 2 RCTs^{20,21} and a Cochrane review.²² In a trial of more than 300 women undergoing nonemergent cesarean section, additional vaginal povidone-iodine scrub in addition to standard abdominal preparation resulted in a lower incidence of postcesarean endometritis (7-14.5%; adjusted odds ratio [OR], 0.44; 95% CI, 0.19-0.99) but not in postoperative fever or wound infection.²⁰ Another RCT of 300 women using a composite infectious morbidity (postoperative fever, endometritis, sepsis, readmission, wound infection, or complication) as its primary outcome noted a nonstatistically significant decrease (6.5-9%; RR, 0.55; 95% CI, 0.26-1.11) in the vaginal cleansing arm.²¹ In a Cochrane review of 4 trials (n = 1198 women), vaginal preparation immediately before cesarean delivery significantly reduced the incidence of postcesarean endometritis (9.4-5.2%; RR, 0.57; 95%

CI, 0.38-0.87), especially in women with ruptured membranes (15.4-1.4%; RR, 0.13; 95% CI, 0.02-0.66).²² Given these findings, preoperative vaginal preparation with povidone-iodine scrub should be considered prior to CD (recommendation: B; level of certainty: moderate; Table 1; new).

Indwelling bladder catheterization

The use or nonuse of an indwelling bladder catheterization at the time of CD was evaluated in 2 RCTs.^{23,24} A recent metaanalysis²⁵ of these trials and 1 prospective nonrandomized control trial (NRCT)²⁶ was notable for a decreased incidence of urinary tract infection in the uncatheterized group (0.5% vs 5.7%; RR, 0.08; 95% CI, 0.01-0.64^{23,24}; 0.6% vs 6.0%; RR, 0.10; 95% CI, 0.02-0.57²⁶) and no difference in urinary retention between groups (2 of 345 vs 0 of 345; RR, 5.00; 95% CI, 0.24-103.18^{23,24}; 2 of 344 vs 0 of 50; RR, 0.74; 95% CI, 0.04-15.18²⁶). Another RCT comparing immediate or 24 hour removal of an indwelling catheter found no significant differences in postoperative urinary retention and a nonsignificant lower incidence of positive urine culture

72 hours postoperatively in the immediate removal group (8.1% vs 11.2%; *P* = .489).²⁷ Given the low incidence of bladder or ureteral injury reported in the literature (bladder 1.4 of 1000 CD and ureteric injury 0.27 of 1000 CD²⁸), these trials were underpowered to detect a difference in these outcomes. In the one study that reported it, operative time was similar in both groups.²⁴ These findings suggest not placing or early removal of indwelling bladder catheters may be considered during CD (recommendation: C; level of certainty: moderate; Table 1; new).

Supplemental oxygen

Supplemental oxygen for the prevention of CD morbidity from infection has been described in 2 RCTs. Both studies randomized patients to either 2 L of oxygen by nasal cannula during CD only (standard care) or 10 L of oxygen by nonbreather mask (intervention group) during and for 2 hours after CD,^{29,30} and neither trial reported a reduction in morbidity from infection among groups and thus cannot be recommended (recommendation: D; level of certainty: high; Table 1; new).

Intraoperative techniques

Skin incision type

This has been evaluated in the context of general approaches to CD (Pfannenstiel, Joel-Cohen, Misgav-Ladach, modified Misgav-Ladach). These methods are summarized in Table 3 and incorporate multiple components, making assessment of each individual CD technique impossible. Four RCTs comparing Misgav-Ladach–based procedures with Pfannenstiel techniques noted improved operating times and possible cost savings in the former with minimal difference in maternal morbidity.^{31–34} A Cochrane review³⁵ and metaanalysis³⁶ of 14 trials ($n = 2906$) noted significantly improved short-term outcomes (less blood loss, less fever, lower duration of postoperative pain) in those techniques using Joel-Cohen–based surgical methods with insufficient data on neonatal or long-term morbidity or mortality (recommendation: C; level of certainty: moderate; Table 1; unchanged).

Dissection of fascia off the rectus muscles

This has been evaluated in one small RCT ($n = 120$).³⁷ Nondissection of the inferior rectus fascia was associated with lower decline of pre- and post-surgical hemoglobin levels (-1.2 g/dL vs -1.6 g/dL, $P = .05$) and less pain as determined by the visual analog scale (23 vs 30 , $P = .03$). Outcomes such as surgical time and degree of difficult delivery of the fetus were not evaluated (recommendation: I; level of certainty: low; Table 1; unchanged).

Bladder flap

The bladder flap development vs no development has been studied in 2 additional RCTs,^{38,39} and closure versus nonclosure of the bladder flap visceral peritoneum has been studied in one RCT.⁴⁰ In a trial of 258 women, omission of the bladder flap at primary and repeat CD shortened incision-to-delivery time but did not increase intraoperative or postoperative complications (estimated blood loss, change in hemoglobin level, postoperative microhematuria, postoperative pain, hospital days, endometritis, or urinary

tract infection).³⁸ In a trial of 620 women undergoing CD, visceral peritoneal closure of the bladder flap increased postpartum urinary frequency and/or incontinence, but these symptoms disappeared without treatment within 6 months.⁴⁰ Routine bladder flap development and/or visceral peritoneal closure do not appear to provide any immediate advantage during CD, but trials have been underpowered to assess morbidity such as bladder injury and adhesion formation (recommendation: D; level of certainty: moderate; Table 1; changed).

Self-retaining retractors

These were evaluated in one feasibility trial of 231 women during CD.⁴¹ Moreover, this study was not powered to assess any meaningful outcomes such as operative times or surgical site infection reduction (recommendation: I; level of certainty: low; Table 1; new).

Expansion of uterine incision

The expansion of uterine incision has been studied in 2 additional RCTs^{42,43} and further summarized in a Cochrane review.⁴⁴ Blunt expansion remains preferred to sharp expansion of the uterine incision with decreased maternal morbidity as measured by estimated blood loss and decrease in hemoglobin.⁴² In a well-designed trial of more than 800 women comparing blunt, transversal vs blunt, cephalad-caudad expansion, unintended extension (defined as any irregularity in the wound edge that required anything more than the standard uterine closure), and blood loss of more than 1500 mL was significantly higher in the transversal expansion group (7.4% vs 3.7% ; $P = .03$, and 2.0% vs 0.2% ; $P = .04$, respectively).⁴³ Thus, blunt cephalad-caudad expansion of the uterine incision is recommended (recommendation: A; level of certainty: high; Table 1; changed).

Prevention of postpartum hemorrhage

The prevention of postpartum hemorrhage using oxytocin infusion, oxytocin bolus, misoprostol, carbetocin, and tranexamic acid has been studied in combination or individually in 13 RCTs

since 2005.^{45–57} There is no standardized dose of oxytocin infusion used in these trials, thus making direct comparison difficult. Doses of continuous oxytocin infusion ranged from 10 to 40 IU in 1 L crystalloid over 4–8 hours and oxytocin intravenous boluses ranging from 0.5 to 5 IU over 30 minutes in these trials. Two RCTs^{47,48} favored continuous intravenous infusion only, whereas 1 trial⁴⁹ found additional benefit from routine oxytocin bolus. These studies suggest that oxytocin infusion (10–40 IU in 1 L crystalloid over 4–8 hours) is effective in uterine atony prevention, with unknown benefit from oxytocin bolus. (recommendation: B; level of certainty: high; Table 1; changed).

Misoprostol in combination or in lieu of oxytocin infusion has been evaluated in 5 RCTs.^{51–55} Misoprostol (200–800 μ g rectal or sublingual) alone was similar in estimated blood loss (EBL) and the need for additional uterotonics as continuous oxytocin infusion in 4 trials.^{51–54} Side effects of shivering, pyrexia, and metallic taste in the misoprostol group was noted in up to 57% of women and unique to this group. In another trial, misoprostol plus routine oxytocin infusion reduced the need for additional uterotonic agents during CD (43% vs 26% ; RR, 1.3; 95% CI, 1.10–1.50).⁵⁵ Misoprostol is not superior to oxytocin in uterine atony prevention with increased side effects of maternal shivering and pyrexia (recommendation: D; level of certainty: moderate; Table 1; new).

Tranexamic acid (10 mg/kg intravenously prior to incision) is an antifibrinolytic and hemostatic agent, and 3 new RCTs have evaluated its use in decreasing blood loss in CD.^{48,56,57} In these trials, tranexamic acid significantly decreased intraoperative and postpartum blood loss (100–200 mL). In one trial, the EBL of greater than 1000 mL and the need for additional uterotonics was significantly lower in the tranexamic acid group (2.1% vs 5.8% ; RR, 2.7; 95% CI, 1.1–6.3; and 8.5% vs 14.5% ; RR, 1.7; 95% CI, 1.1–2.6, respectively)⁴⁸ (recommendation: B; level of certainty: moderate; Table 1; new).

Carbetocin, an oxytocin agonist administered in a single dose (100 μ g

intravenously after delivery) has been compared with oxytocin in 2 additional RCTs. Although women allocated to Carbetocin required fewer additional oxytocic agents, there was no significant differences between groups in major postpartum hemorrhage, blood transfusion, or fall in hemoglobin^{45,50} (recommendation: C; level of certainty: moderate; Table 1; unchanged).

Placental drainage

Placental drainage, the act of allowing fetal blood to egress both passively and actively by milking the umbilical cord after the cord is clamped and cut, has been evaluated in 1 RCT. In 86 women, placental drainage was associated with a significant decrease in fetomaternal transfusion as measured by a postpartum positive Kleihauer-Betke test (6.8% vs 33%; RR, 0.2; 95% CI, 0.065–0.65).⁵⁸ However, given the small sample size of the trial, there is insufficient evidence to justify this technique (recommendation: I; level of certainty: low; Table 1; new).

Uterine exteriorization

Uterine exteriorization for hysterotomy repair has been evaluated in 7 additional RCTs^{59–65} and summarized in a metaanalysis.⁶⁶ When analyzing the pooled data including 3183 women, febrile complications and surgical time were similar between uterine exteriorization and intraabdominal repair. Thus, the decision to exteriorize the uterus should be guided by provider preference (recommendation: C; level of certainty: high; Table 1; changed).

Cervical dilation

After placental removal, either manually or via the use of surgical instruments, cervical dilation has been evaluated in 3 RCTs^{67–69} and a Cochrane review (n = 735).⁷⁰ There was no difference in morbidity from infection between groups, and hematometra was not assessed in these trials (recommendation: D; level of certainty: high; Table 1; new).

Closure of the uterine incision

Closure of the uterine incision with single- vs double-layer closure has been compared in 1 RCT,⁷¹ 1 metaanalysis,⁷²

and 1 updated Cochrane review.⁴⁴ In the largest randomized trial of CD techniques undertaken to date (n = 3033), participants were randomized to 2 of 3 of the following techniques: single- vs double-layer uterine closure, peritoneal closure vs nonclosure, and liberal vs restrictive subsheath drainage.⁷⁴ All of the short-term outcomes including morbidity from infection (primary outcome), surgery duration, pain, the need for blood, hospital readmission, breast-feeding, and transfusion were no different between the groups. The role of a single- vs double-layer closure for reducing a subsequent uterine rupture remains controversial. The evidence that 2-layer closure reduces this risk is derived from cohort or case-control studies in which women were not randomly allocated to 1- or 2-layer closure. Therefore, definitive recommendations regarding subsequent uterine rupture risk are not possible in women with desired future fertility (recommendation: C; level of certainty: moderate; Table 1; changed). In women with undesired fertility, there does not appear to be any benefit of a 2-layer uterine closure (recommendation: A; level of certainty: high; Table 1; changed).

Elective appendectomy

Elective appendectomy during CD performed by the obstetrician/gynecologist has been studied in 1 small RCT.⁷³ In this trial (n = 93), coincidental appendectomy was associated with a significant increase in operative time by approximately 8 minutes (P = .03) with no increase in febrile morbidity (recommendation: D; level of certainty: moderate; Table 1; new).

Intraabdominal irrigation

Intraabdominal irrigation with normal saline before abdominal closure has been evaluated in 1 RCT.⁷⁴ The rate of intraoperative nausea was significantly increased (OR, 1.62; 95% CI, 1.15–2.28) in the intraabdominal irrigation group with no difference in estimated blood loss, operating time, intrapartum complications, hospital stay, return of gastrointestinal function, or infectious complications (recommendation: D;

level of certainty: moderate; Table 1; unchanged).

Peritoneal closure

Peritoneal closure vs nonclosure has been evaluated in 7 additional RCTs,^{71,75–80} 2 metaanalyses,^{81,82} and 1 systematic review.⁸³ Some trials focused specifically on parietal or visceral peritoneum closure, whereas others reported both together. In one recent RCT of 533 women undergoing primary CD randomized to closure vs nonclosure, 50 women in the nonclosure group and 47 women in the closure group were subsequently evaluated intraoperatively at a repeat cesarean.⁷⁶ The presence and severity of adhesions were comparable among both groups (60% vs 51%, P = .31). In contrast, a meta-analysis including 4423 women retrospectively evaluated intraabdominal adhesion formation among 3 different CD surgical techniques.⁸¹ Of note, these trials were not evaluating peritoneal closure alone, but a subset (n = 1161) of women underwent CD with techniques similar in all steps except closure (Misgav-Ladach) or nonclosure (modified Misgav-Ladach) of the peritoneum. In this cohort, there was an increased risk of intraabdominal adhesions in the nonclosure group (OR, 4.69; 95% CI, 3.32–6.62). Surgeons must balance the advantage of nonclosure in regard to less postoperative fever, less operating time, and reduced hospital stay and understand that limited data suggest parietal peritoneal closure may decrease the risk of future adhesions (recommendation: C, level of certainty: moderate; Table 1; changed).

Sharp vs blunt needles

Sharp vs blunt needles for the closure of tissue layers during CD has been evaluated in 1 additional RCT⁸⁴ and 1 Cochrane review.⁸⁵ In the RCT, the use of blunt needles was found to significantly reduce the overall risk of glove perforation (7.2% vs 17.5%; RR, 0.66; 95% CI, 0.49–0.89). The Cochrane review analyzed 10 RCTs involving 2961 participating surgeons comparing the usage of blunt needles with sharp needles but was not limited to CD.⁸⁵ In the

4 studies focusing on abdominal closure, the use of blunt needles reduced the number of percutaneous exposure incidents (1.3% vs 5.8%; RR, 0.31; 95% CI, 0.14–0.68), translating into an estimated 1 glove perforation prevented for every 6 operations.⁸⁵ Blunt needles are effective in reducing needle stick injuries and should be routinely available, accessible, and routinely used in all CDs (recommendation: A; level of certainty: moderate; Table 1; changed).

Subcutaneous closure vs drain

Subcutaneous closure vs drain has been evaluated in 1 RCT⁷¹ and included in a recent metaanalysis.⁸⁶ Liberal vs restricted use of subcutaneous drains was not associated with a decrease in morbidity from infection (16% vs 18%; RR, 1.08; 95% CI, 0.92–1.27).⁷¹ A meta-analysis evaluating 6 randomized trials showed that prophylactic drainage was not associated with decreased wound infection (OR, 1.15; 95% CI, 0.70–1.90), hematoma (OR, 1.05; 95% CI, 0.33–3.30), or seroma (OR, 0.44; 95% CI, 0.14–1.43).⁸⁶ Subcutaneous closure with or without a drain when the thickness is greater than 4 cm was evaluated in 1 RCT and found no difference in wound morbidity between groups (RR, 1.3; 95% CI, 0.8–2.1).⁸⁷ Suture closure of subcutaneous tissue thickness of 2 cm or greater is recommended (recommendation: A; level of certainty: high; Table 1; unchanged), whereas the subcutaneous drain placement, regardless of tissue thickness, does not appear to offer any additional benefit in reducing wound morbidity (recommendation: D; level of certainty: high; Table 1; changed).

Skin closure

Skin closure using staples or subcuticular suture has been evaluated in 5 recent RCTs^{88–92} and summarized in 2 meta-analyses^{93,94} and 1 Cochrane review.⁹⁵ Trials differed in both suture material used for closure and primary outcomes. In a review of 5 RCTs and 1 prospective cohort study, staple closure (n = 803) was associated with a 2-fold higher risk of wound infection or separation compared with subcuticular suture closure (n = 684) (13.4% vs 6.6%; pooled OR, 2.06;

TABLE 4
Recommended cesarean delivery techniques

Cesarean delivery techniques	Recommendations with high level of certainty ^a
Recommended	
Prophylactic antibiotics	Single dose, ampicillin or first-generation cephalosporin 15-60 min prior to incision
Expansion of uterine incision	Blunt, cephalad-caudad direction
Prevention of PPH	Oxytocin infusion (10-40 IU in 1 L crystalloid over 4-8 h)
Placental removal	Spontaneous
Uterine exteriorization	Surgeon preference
Uterine closure	One-layer if future fertility undesired
Subcutaneous closure	Suture closure if ≥ 2 cm
Not recommended	
Supplemental oxygen	Does not reduce morbidity from infection
Cervical dilation	Does not reduce morbidity from infection
Subcutaneous drain	Does not reduce wound morbidity

PPH, postpartum hemorrhage.

^a See Table 1. The available evidence usually includes consistent results from well-designed, well-conducted studies in representative primary care populations. These studies assess the effects of the preventive service on health outcomes. This conclusion is therefore unlikely to be strongly affected by the results of future studies.

Dahlke. Evidence-based cesarean delivery. *Am J Obstet Gynecol* 2013.

95% CI, 1.43–2.98).⁹⁴ In contrast, a recent Cochrane review of 8 trials (n = 1665) concluded that wound complications and cosmetic outcomes were similar among both groups.⁹⁵ Given the conflicting data, it is uncertain whether sutures or staples are superior, making a definitive recommendation difficult (recommendation: C; level of certainty: moderate; Table 1; changed).

Comment

Worldwide, cesarean delivery is the most frequent major operation performed. Therefore, it is imperative that surgeons who perform the operation use techniques that have been shown to minimize maternal morbidity and mortality. Fortunately, several aspects of the surgery are supported by evidence with a high level of certainty as defined by the USPSTF: previously, Berghella et al⁴ identified 5 such technical aspects, and the newer trials reviewed herein now support 10 such CD techniques (Table 4).

We acknowledge that our review has some limitations. Our recommendations

are constrained by the specific questions the various RCTs asked. Indeed, many of these questions were narrowly focused on short-term outcomes or outcomes of arguable clinical importance. Most of the trials were not blinded and across trials, interventions, techniques, and outcomes were somewhat heterogeneously defined. Despite these shortcomings, one benefit of using USPSTF terminology is that both a recommendation and the level of certainty based on the quality of evidence can be assigned for each CD technique and communicated among clinicians and researchers.

Several important technical aspects of CD have not been sufficiently evaluated. Specifically we believe trials that evaluate means of reducing CD-associated VTE and hemorrhage are urgently needed. In the United States, 10.9% of maternal deaths are associated with VTE.⁹⁶ It has been estimated that the risk of CD-associated VTE is at least 0.23%¹⁹ or approximately 1 in 400 surgeries, a rate that is twice that associated with vaginal delivery.⁹⁷ However, it remains unclear whether pharmacological or mechanical

measures (or both) should be routinely utilized to reduce the risk of CD-associated VTE. With the former, iatrogenic hemorrhage is a concern, and both are costly. We estimate that a definitive trial powered to detect a 50% reduction (0.25-0.125%) in CD-associated VTE using 1 of these methods VTE would require approximately 40,000 participants equally divided in a control or intervention group (2-tailed $\alpha = 0.05$, $\beta = 0.2$). Although a trial of this magnitude would be daunting, it is worth bearing in mind that 1.3 million CDs are performed each year in the United States alone. Thus, a trial of 40,000 participants would require 3% of these surgeries.

Similar to VTE, postpartum hemorrhage accounts for an appreciable proportion (11.9%) of pregnancy-related maternal death in the United States.⁹⁶ Additionally, 2-3% (approximately 40,000 each year) of all women in the United States who undergo CD require a blood transfusion.⁹⁸ Therefore, evaluating methods for minimizing CD-associated blood loss should remain a research priority. Specifically, interventions whose primary outcome is a reduction in blood transfusions seem to be in order. For example, we estimate a trial powered to detect a 50% reduction (3-1.5%) in blood transfusion for a given intervention (eg, tranexamic acid) would require 3400 participants equally divided in a control or intervention group (2-tailed $\alpha = 0.05$, $\beta = 0.2$).

Finally, whether the technique of 2-layer closure of the hysterotomy at the time of CD lowers the risk of subsequent uterine rupture is a question that has not been answered or adequately assessed in women randomized to 1- or 2-layer closure. Fortunately, in the CAESAR collaborative, more than 3000 women were randomized to 1- or 2-layer uterine closure,⁷¹ and the recently completed international study of cesarean section techniques (CORONIS collaborative)⁹⁹ randomized almost 16,000 women to this technical aspect of CD. Long-term follow-up of these large trials is planned and may offer the best opportunity to answer this long-standing question (personal communication, chief investigator, Peter Brocklehurst).

The cesarean delivery technique has certainly evolved since it was first described in the medical literature in 1610 AD¹⁰⁰ and will undoubtedly continue to be refined with subsequent decrease in morbidity. As results from well-designed, Consolidated Standards of Reporting Trials (CONSORT) compliant RCTs provide evidence suggesting best surgical practices that minimize surgical morbidity, it is incumbent on clinicians to adopt evidence-based techniques when performing and teaching CD. ■

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